Rectal Cancer: Review with Emphasis on MR Imaging

One concern after rectal cancer surgery is the high local recurrence rate. Randomized trials have shown that the best local control rate for rectal cancer patients as a group is achieved after a short course of radiation therapy followed by optimal surgery. It is debatable, however, whether all patients with rectal cancer should undergo preoperative radiation therapy. Preoperative identification of those most likely to benefit from neoadjuvant therapy is important. Therefore, the challenge for preoperative imaging in rectal cancer is to determine subgroups of patients with different risks for recurrence: those with superficial tumors, who can be treated with surgery alone; those with operable tumors and a wide circumferential resection margin, who can be treated with a short course of radiation therapy followed by total mesorectal excision; and those with advanced cancer and a close or involved resection margin, who require a long course of radiation therapy, with or without chemotherapy, and extensive surgery. So far, there is no consensus on the role of diagnostic imaging (endorectal ultrasonography, computed tomography, and magnetic resonance [MR] imaging) in the care of patients with primary rectal cancer. Preoperative staging has long relied on digital examination alone, which indicates that it has been difficult to achieve accuracy levels high enough for clinical decision making with preoperative imaging. In this review, the relevance of preoperative imaging in staging the local extent of primary rectal cancer will be discussed. Research on various imaging modalities, with an emphasis on MR, will be discussed under four main headings that address the most relevant aspects of local spread of rectal tumors: T stage, circumferential resection margin, locally advanced rectal cancer, and N stage.

Rectal cancer is associated with a poor prognosis because of the risk both for metastases and for local recurrence. After curative resection of the rectum for rectal cancer, local recurrence rates can vary from 3% to 32% (1). Incomplete removal of the lateral spread of the tumor is now accepted as the cause of the majority of these recurrences (2,3). Quirke et al (3) demonstrated that microscopically positive resection margins resulted in a local recurrence rate of 83%. Although local recurrence has a small effect on survival rate, it has a profound influence on the quality of life. A local recurrence is often debilitating because of severe pain and immobility and prolonged and multiple hospital admissions for surgery, radiation therapy, and chemotherapy. Attention has, therefore, been directed mainly at defining the best treatment strategy for the primary tumor in order to obtain optimal local control.

Since the results of large European randomized trials, there has been renewed interest in preoperative radiation therapy for patients with mobile rectal cancer (4). Whereas in the United States, postoperative combined chemotherapy and radiation therapy has been the standard treatment for patients with T3 and/or N1 rectal cancer (5)—with this therapy mainly restricted to patients with fixed tumors—preoperative radiation therapy is the standard for all rectal cancer patients in Europe. A Scandinavian randomized trial showed that a short course of preoperative radiation therapy (five treatments of 5 Gy each) reduces the local recurrence rate from 27% to 11% (6).

At the same time, the surgical technique was standardized by the introduction of total mesorectal excision (TME) (7). The mesorectum consists of the rectum and the surrounding mesorectal fat with the perirectal lymph nodes and is enveloped by a thin fascia known as the mesorectal fascia (Fig 1). In TME, the entire mesorectal compartment is removed, including its fascia; this minimizes the chance of tumor being left behind. With this...
ESSENTIALS

- Helping improve therapeutic management of rectal cancer is a challenging task for radiologists.
- On the basis of different risk categories, patients are treated with different regimens of surgery, radiation therapy and chemotherapy.
- Assessment of the local spread of a tumor includes determination of the depth of tumor growth in the rectal wall, the CRM at TME, the depth of tumor invasion in surrounding pelvic structures, and nodal status.
- Endorectal US remains the most accurate staging tool for superficial rectal cancer but is less suitable for advanced tumors.
- Current evidence suggests that MR imaging is the most reliable technique to help determine the CRM and surrounding organ invasion.

surgical technique, the overall recurrence rate has been reported to be well below 10%, without the help of radiation therapy (7). The relative merits of both strategies, TME and preoperative radiation therapy, have recently been tested in a Dutch randomized trial (8) in which TME with a preoperative short course of radiation therapy was compared with TME without radiation therapy. The results of the trial showed that a short course of preoperative radiation therapy reduces the local recurrence rate from 8.2% to 2.4% at 2 years. These results imply that even with a properly performed TME, patients with rectal cancer benefit from preoperative radiation therapy.

The Dutch TME trial, however, also showed that there are groups of rectal cancer patients with differing degrees of risk for local recurrence. At one end of the spectrum is the low-risk group: patients with superficial rectal cancer (stage I), who can be treated with surgery alone (TME or transanal resection). At the other end is the high-risk group: patients with a close or involved resection margin at TME, the very advanced tumors, that probably require more than the standard treatment—a longer course of chemotherapeutic treatment and extensive surgery (9). Paramount for this selection and differentiated treatment is a reliable preoperative test that can be used to distinguish between these groups.

So far there has been no consensus on the role of diagnostic imaging in the care of patients with primary rectal cancer. Patients are often considered for surgery without undergoing preoperative imaging of the pelvic area. This indirectly indicates that it has been difficult to achieve accuracy levels that are high enough for clinical decision making with preoperative imaging. There have been many reports on rectal cancer imaging with endorectal ultrasonography (US), computed tomography (CT), or MR imaging, but most studies focused only on determination of T and N stage rather than on the more relevant mesorectal fascia.

In this review, we will discuss the relevance of preoperative imaging in staging of the local extent of primary rectal cancer. Research on the various imaging modalities, with an emphasis on MR imaging, will be discussed under four main headings that address the four most relevant aspects of the local spread of rectal tumors: tumor stage (T stage) (Table), circumferential resection margin (CRM), locally advanced rectal cancer, and regional nodal metastasis stage (N stage).

The role of imaging in the detection of locally recurrent rectal cancer will not be discussed in this review.

T STAGE

Endorectal US is now an established modality for evaluation of the integrity of the rectal wall layers. With accuracies for T staging varying between 69% and 97%, endorectal US is presently the most accurate imaging modality for the assessment of tumor ingrowth into rectal wall layers (10–27). In a meta-analysis (28) of 11 studies, sensitivity was shown to be affected by T stage. Endorectal US is very accurate for staging of superficial rectal tumors but is not as useful for staging of advanced rectal cancer. A recent large study on endorectal US (19) in 1,184 patients with rectal tumors confirmed these findings. The overall staging accuracy of 69% for US in that study was lower than previously reported values because the limited depth of acoustic penetration prevents accurate assessment of local tumor extent in bulky T3 and advanced rectal cancers. Another reason for the discrepant results of that study was the operator-dependent nature of US and substantial interobserver variability, which was also reported in previous studies on endorectal US (19,29–31). Although endorectal US is very accurate for staging of superficial rectal cancer, it is less suitable for evaluation of the mesorectal excision plane.

CT has the advantage of allowing imaging of the whole pelvis (32). Initial studies (32–37) with conventional CT mainly focused on locally advanced rectal cancer, and high accuracies for T staging were reported to vary between 79% and 94%. However, later studies (10,22,38–43) that included less advanced tumors have shown accuracies that were not as high as anticipated, varying between 52% and 74%. In a recently published meta-analysis (44) of 78 studies conducted between 1980 and 1998 in 4,897 patients with rectal cancer, CT showed an accuracy of 73% for T staging. The low spatial and contrast resolution of conventional CT protocols does not allow a detailed evaluation of the rectal wall and may have contributed to the low performance of CT for staging of superficial tumors.

The successful introduction of MR imaging for pelvic diseases has, in recent years, led to the gradual replacement of CT by MR imaging for local and regional rectal cancer staging. Initial MR studies were performed with a body coil. Because conventional body coil techniques showed a resolution that was still insufficient to differentiate the individual layers of the rectal wall, overall accuracies reported for MR imaging with a body coil have not been any better than those reported for CT, with values ranging from 59% to 88% (37,39,41,43,45–47).

The introduction of endoluminal coils facilitated improved image resolution and made detailed evaluation of the layers of the rectal wall feasible (48). This was also reflected in improved and more consistent T staging, with accuracy ranging between 71% and 91% (21,26,49–54). Endorectal MR imaging can be as accurate as endorectal US for staging of superficial tumors, as shown in studies comparing the two endoluminal techniques (21,26,52). However, some problems remain with endorectal MR imaging. Besides the limited availability and high cost, MR imaging with an endoluminal coil, especially when used in isolation, has a limited field of view. Like endorectal US, the mesorectal fascia and surrounding pelvic structures are difficult to visualize owing to the sudden signal drop-off at a short distance from the coil.
Figure 1. Magnetic resonance (MR) imaging anatomy of the mesorectum and the mesorectal fascia. Transverse T2-weighted turbo spin-echo (repetition time msec/echo time msec, 3,427/150; field of view 20 × 20 cm; matrix 256 × 179; echo train length, 25; number of signals acquired, eight; section thickness, 4 mm) MR image of rectum and mesorectum. Mesorectum consists of rectum (arrows) and surrounding mesorectal fat (*) with perirectal lymph nodes. It is enveloped by the thin mesorectal fascia (arrowheads).

Figure 2. Transverse contrast material–enhanced CT scan in a 62-year-old man with rectal cancer shows rectal tumor (arrows) limited to the mesorectum. It is difficult to accurately predict on the basis of CT scans whether tumor is limited to (T2) or has just breached the rectal wall (T3). Owing to inherent low contrast and spatial resolution of conventional CT techniques, the muscular rectal wall cannot be clearly delineated.

Figure 3. T2-stage rectal cancer overstaged at MR imaging as a T3-stage tumor in a 67-year-old woman. (a) Transverse T2-weighted turbo spin-echo (3,427/150; field of view, 20 × 20 cm; matrix, 256 × 179; echo train length, 25; number of signals acquired, eight; section thickness, 4 mm) MR image shows almost-circumferential rectal stranding from tumor into perirectal fat (arrowheads), this tumor was staged T3. Mesorectal fascia (black arrows) is clearly depicted. CRM of more than 10 mm was predicted. (b) Corresponding microscopy section demonstrates tumor (black arrows) limited to the rectal wall (white arrow). Spiculations consisted of desmoplastic reaction alone (arrowheads), with no tumor cells. (Hematoxylin-eosin stain; original magnification, ×25.) (Reprinted, with permission, from reference 64.)

TNM Staging Classification of Colon and Rectal Cancer

<table>
<thead>
<tr>
<th>Stage</th>
<th>Characteristic</th>
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<tbody>
<tr>
<td>Tumor</td>
<td>Tumor invades submucosa</td>
</tr>
<tr>
<td>T1</td>
<td>Tumor invades muscularis propria</td>
</tr>
<tr>
<td>T2</td>
<td>Tumor invades through muscularis propria into subserosa or nonperitonealized pericolic or perirectal tissues</td>
</tr>
<tr>
<td>T3</td>
<td>Tumor directly invades other organs or structures and/or perforates visceral peritoneum</td>
</tr>
<tr>
<td>T4</td>
<td>Tumor invades through muscularis propria into subserosa or nonperitonealized pericolic or perirectal tissues</td>
</tr>
<tr>
<td>Regional nodal metastasis</td>
<td>Regional lymph nodes cannot be assessed</td>
</tr>
<tr>
<td>NX</td>
<td>No nodal metastasis</td>
</tr>
<tr>
<td>N0</td>
<td>Metastasis in one to three pericolic or perirectal nodes</td>
</tr>
<tr>
<td>N1</td>
<td>Metastasis in four or more pericolic or perirectal nodes</td>
</tr>
<tr>
<td>N2</td>
<td>Metastasis in any node along course of a named vascular trunk and/or metastasis to apical node(s)</td>
</tr>
<tr>
<td>N3</td>
<td>Metastasis in any one of the regional lymph nodes</td>
</tr>
<tr>
<td>Distant metastasis</td>
<td>Presence of distant metastasis cannot be assessed</td>
</tr>
<tr>
<td>MX</td>
<td>No distant metastasis</td>
</tr>
<tr>
<td>M0</td>
<td>Distant metastasis</td>
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(55). Furthermore, the positioning of an endoluminal device can be difficult or impossible in patients with high and/or stenosing tumors, and failed insertion rates of as high as 40% have been reported in patients with rectal cancer (56).

With the introduction of dedicated external coils, especially phased-array coils, improvement in MR imaging performance was expected (57–61). The advantages of high spatial resolution with a large field of view make phased-array MR imaging suitable for staging of both superficial and advanced rectal tumors. However, authors of the first studies that used MR with the multiple surface coil technique reported an overall accuracy for T staging of only 55%–65% and showed no benefit compared with use of a body coil or even with CT (62,63). The low performance of MR imaging in these studies could have been attributed to the low spatial resolution that was used with the early phased-array techniques. But even when a higher spatial resolution was applied with the new generation of phased-array coils, the accuracy for T staging was not as high as anticipated, with values varying between 65% and 86% (61,64–66), and was not as reproducible as expected, with considerable interobserver variability (64). One exception to the above was the study by Brown and colleagues (60), who reported 100% accuracy and complete agreement between two readers on the prediction of tumor stage with phased-array MR imaging results.

Most staging failures with MR imaging occur in the differentiation of T2-stage and borderline T3-stage lesions, with overstaging as the main cause of errors. Overstaging is often caused by desmoplastic reactions (54,60,64,67), and it is difficult to distinguish on MR images between spiculation in the perirectal fat caused by fibrosis alone (stage pT2) and spiculation caused by fibrosis that contains tumor cells (stage pT3) (Figs 3, 4) (64).
The present T-staging system is sometimes used for clinical decision making. Postoperative combined chemotherapy and radiation therapy has been the standard in the United States for patients with T3- and/or N1-stage tumors. There is now a growing tendency to give the adjuvant therapy preoperatively and, therefore, a need for a good imaging method to select patients at high risk. In this respect, the present T-staging system does have its shortcomings: It does not discriminate between tumors with a wide CRM and tumors with a close or involved CRM (Fig 5). Although most of these tumors are classified as stage T3, they have a different risk for local recurrence. It has been repeatedly shown that the distance from the tumor to the circumferential mesorectal resection plane is a more powerful predictor for the local recurrence rate than is the T stage (3,7,68,69). It is, therefore, probably more important to use imaging to identify those tumors that will have a close or involved resection margin so that they can be selected for more extensive (neoadjuvant) treatment (Figs 6, 7).

CRM AND MESORECTAL FASCIA

Editorials in The Lancet, New England Journal of Medicine, and European Journal of Surgery (70–72) have stressed the importance of a differentiated treatment in patients with rectal cancer and the need for an accurate tool to select patients on the basis of risk factors. Prediction of the CRM has not been the subject of many imaging studies. An initial report on the identification of the mesorectal fascia by using imaging dates from 1983 (35); since that time, however, nothing to our knowledge had been published until only very recently (73).

So far, there have been four reports of which we are aware in the literature on MR evaluation of the mesorectal fascia and the CRM. A recent report by Brown et al (74) of a study in 98 rectal cancer patients showed 92% agreement between MR images and histologic findings for prediction of the CRM. Blomqvist and colleagues (73) used postoperative MR images of 26 resected rectal tumor specimens and were able to predict tumor involvement of the CRM with high accuracy.

Results of a study conducted by our team were published in The Lancet in early 2001 (64). By using a high-spatial-resolution phased-array MR technique (see Appendix), 76 patients were studied, and the images were evaluated by two radiologists with different MR experience. The accuracy for T staging was 83% for observer 1 and 67% for the less experienced observer 2. For 12 T4 tumors with involved mesorectal fascia and, thus, a CRM of 0 mm, the accuracy in predicting the CRM was 100% for both readers. In 29 patients with a wide CRM (>10 mm), the accuracy for predicting this wide margin was 97% (28 of 29) for reader 1 and 93% (27 of 29) for reader 2. For distances of 1–10 mm, a linear regression curve showed that the crucial distance of at least 2 mm can be predicted with 97% confidence when the distance on MR images is at least 6 mm (68). An important finding was the high agreement of the CRM measurements both between (intraclass correlation coefficients, 0.99 and 0.91) and within (intraclass correlation coefficient, 0.93) the observers, which was in contrast to the only moderate intra- and interobserver agreement for T-stage determination (κ = 0.53). This indicates that phased-array MR is highly accurate and reliable for prediction of the CRM. It is less accurate and less consistent for prediction of the correct T stage. These results were confirmed in a study with 43 patients by Bissett and colleagues (75). They not only reported a 95% accuracy for the MR prediction of tumor penetration through the mesorectal resection plane but also proved, in a cadaver study, that the fascia that can be visualized on high-spatial-resolution phased-array MR images is indeed the mesorectal fascia.

LOCALLY ADVANCED RECTAL CANCER

Ten percent to 20% of rectal tumors are locally advanced, with fixation to surrounding pelvic structures (Figs 8, 9). In
In these cases, the patient’s best chance for cure is a radical en bloc resection of the tumor and the surrounding invaded organs (76). Accurate and detailed anatomic information on tumor extent is essential not only for the selection of patients for neoadjuvant chemotherapy and radiation therapy to achieve tumor shrinkage but also for planning of the optimal surgical procedure (1).

Only a few studies on imaging have addressed the problems of predicting primary rectal tumor infiltration into neighboring organs (39,63,65,77). Because of the initial optimistic results regarding CT for staging of advanced rectal cancer (32,33,37,42,43,78), this modality has long been used to evaluate the local tumor extent in patients with fixed rectal cancer. Although CT has often been compared with MR imaging in the follow-up of rectal cancer patients for early detection of local tumor relapse, to our knowledge only a few publications exist in which both modalities were compared in terms of prediction of the local extent of advanced rectal cancer (79–81). In an early study, Blomqvist et al (81) found better prediction for organ invasion with pelvic phased-array MR imaging (six of nine) than with CT (three of nine), but this conclusion was based on results in a limited number of patients. The same authors recently published a study (80) with 16 patients with advanced rectal cancer and compared MR imaging with CT. They found superior performance for MR in prediction of bladder and uterine...
invasion (Figs 10, 11) (65). We compared phased-array MR imaging with CT in 26 patients with advanced or recurrent rectal cancer and found MR to be far more accurate than CT in the prediction of organ invasion, pelvic wall invasion, and subtle bone marrow invasion (79) (Figs 12, 13).

At present, the literature indicates that MR imaging is superior to CT for prediction of tumor invasion in surrounding pelvic structures. However, the large difference in outcome between the two modalities could be partially attributed to the fact that a state-of-the-art MR technique was compared with conventional CT techniques (79). In theory, the new-generation multi-detector row spiral CT scanners, with superior contrast and spatial resolution and capability for reconstructions in multiple planes, are expected to provide better performance than conventional CT scanners (82,83). So far, there are only two studies of which...
we are aware on spiral CT of rectal cancer. A study in 20 patients in which conven-
tional CT was compared with multi-
detector row spiral CT showed the latter to be
superior for prediction of T stage, but both
types were equal for prediction of N stage
(84). In a report on 105 rectal cancer pa-
tients undergoing spiral CT (82), an
improved overall accuracy for T staging (82%)
was reported, but only four T4 tumors were
included in that study.

Results of further studies are awaited to
determine if new-generation CT can com-
pete with MR imaging. CT would have the
advantage that a single investigation can
be used to combine local, regional, and
distant staging. With that capability and the
addition of fast acquisition time and rela-
tively low cost, staging with CT would be
beneficial for both the patient and the
health care system.

N STAGE

Rectal cancer has two main routes of lym-
phatic spread. For the upper portion of

Figure 12. MR imaging is superior to CT for
prediction of pelvic wall involvement from lo-
cally recurrent rectal cancer. (a) Transverse
contrast-enhanced CT scan shows mass (ar-
rows) in left lower pelvis of a 66-year-old man
who underwent resection of rectal cancer 2
years previously. Diagnosis of local recurrence
was made on the basis of involvement of left
piriform muscle (arrowheads) and was con-
firmed at biopsy. (b) Coronal T2-weighted
turbo spin-echo (3,427/150; field of view, 20 ×
20 cm; matrix, 256 × 179; echo train length,
25; number of signals acquired, eight; section
thickness, 4 mm) MR image in same patient
clearly shows that tumor (black arrows) does
not invade the left piriform muscle. An intact
fat plane is still seen between tumoral and
muscle tissues (white arrows). Multiplanar im-
aging capability and superior soft-tissue con-
trast resolution of MR allow more confident
diagnosis of the exact extent of tumor invasion
into surrounding structures.

Figure 13. MR imaging is superior to CT for
prediction of pelvic wall involvement from lo-
cal recurrent rectal cancer. (a) Transverse
contrast-enhanced CT scan shows enhancing mass
(arrow) in presacral space in a 55-year-old man
who underwent resection of rectal cancer 1½
years previously. Diagnosis of local recurrence
was confirmed at biopsy. At CT, the exact ex-
tent (arrowheads) of tumor into right piriform
muscle was difficult to predict. (Reprinted,
with permission, from reference 79.) (b) Trans-
verse contrast-enhanced T1-weighted turbo spin-echo
(612/15; field of view, 20 × 15 cm; matrix, 512 × 384; echo train length, five;
number of signals acquired, six; section thickness, 4 mm) MR images of
rectal cancer with involved nodes in mesorec-
tal fat. (a) Rectal tumor (arrows) with involved
perirectal nodes (arrowheads) are all located
within the mesorectum in a 69-year-old
woman. (b) Rectal tumor (arrows) with in-
volved perirectal nodes (arrowheads) are lo-
cated within mesorectum in a 70-year-old
man. Mesorectum is enveloped by mesorectal
fascia. In TME, the entire mesorectum is re-
moved, including fascia and nodes.

Figure 14. Transverse contrast-enhanced T1-
weighted turbo spin-echo (612/15; field of
view, 20 × 15 cm; matrix, 512 × 384; echo train length, five; number of signals acquired,
six; section thickness, 4 mm) MR images of
rectal cancer with involved nodes in mesorec-
tal fat.
the rectum, the route is upward along the superior rectal vessels to the inferior mesenteric vessels. The lower portion of the rectum shows an additional lateral lymphatic route along the middle rectal vessels to the internal iliac vessels. Downward spread along the inferior rectal vessels to the groin is unusual except in very advanced cases and when the anal canal is involved.

Results of early anatomic studies (85–89) showed that over half of the metastatic nodes were within 3 cm of the primary tumor and were smaller than 5 mm in size. With standard TME, the perirectal nodes are removed with the primary tumor (Fig 14) but the internal iliac nodes are left in situ (Fig 15). In lower rectal cancer, therefore, there is a risk that involved internal iliac nodes will be left behind, with the chance for local recurrence (Fig 16). The magnitude of this risk was illustrated by Moriya et al (90), who showed that as many as 28% of lymph node–positive distal rectal cancers have involvement of lateral nodes, and in 6% of cases those lateral nodes were the only lymph nodes involved. This means that disease in 6% of patients is incorrectly staged as node-negative at TME. The fact that nodal disease is a prognostic indicator not only for distant metastases but also for local recurrence has been confirmed in the large Dutch TME trial (8), where patients with stage III (T3N1) disease had a 10-fold higher risk for local recurrence than did those with stage I (T1–2N0 stage) disease and a threefold higher risk than did those with stage II (T3N0 stage) disease.

When the treatment strategy is postoperative chemotherapy and radiation therapy for patients with T3N1 disease, there is little need to identify the lymph node status preoperatively. When the emphasis is on preoperative radiation therapy, with or without chemotherapy, and one wants to select patients at high risk, determination of lymph node status becomes essential.

Some surgeons, mainly from Japan, claim improved local control by adding extended pelvic lymphadenectomy to resection of the rectum. This approach is not favored by most surgeons because of the additional urologic and sexual morbidity, while the benefit is unclear. Again, selection of those patients with the highest risk for lateral lymph node metastases could be useful for centers where pelvic lymphadenectomy is practiced.

Identification of nodal disease is still a diagnostic problem for the radiologist. Despite the identification of lymph nodes as small as 2–3 mm on high-spatial-resolution images, reliable detection of nodal metastases is presently not possible. The radiologic assessment of nodal involvement generally relies on morphologic criteria such as the size and shape of the node (91–93). The problem with morphologic imaging, however, is that with enlarged nodes it is difficult to distinguish between reactive and metastatic nodes, and with small nodes micrometastases are easily missed. An additional problem in rectal cancer, as compared with other pelvic tumors, is the high frequency of micrometastases in normalized sized nodes (86–89). Large variations in accuracy (62%–83%) for nodal detection can be found for endorectal US (10,12,14,16,44,94,95), as well as for CT (22%–73%) (44,45,96–98). Despite the superior soft-tissue contrast, it has not been possible with unenhanced MR imaging to accurately distinguish between inflammatory and metastatic nodes on the basis of signal intensity criteria, nor has the use of nonspecific MR contrast agents improved detection accuracy. Accuracy rates for nodal detection with unenhanced MR imaging vary between 39% and 95% (37,43–46,50–52,99–101).

An alternative method would be metabolic imaging by fluorodeoxyglucose positron emission tomography (PET). Fluorodeoxyglucose PET scanning has been shown to be useful in the management of recurrent rectal cancer (102–107). For primary rectal cancer, there may be some benefit in terms of the detection of distant metastases, but to our knowledge there has been only one study (108) that focused on nodal staging, and a disappointingly low sensitivity of 29% was reported in that study. The reason for the low sensitivity may well be that the proximity of the primary tumor to the urinary bladder obscures small nodal metastases.

Recently, MR imaging with the use of ultrasmall superparamagnetic iron oxide (USPIO) contrast agents has shown promising results for staging nodal metastases. USPIO is a contrast agent that undergoes phagocytosis by the reticuloendothelial system (macrophages in normal lymph nodes). The use of USPIO results in shortening of the T2* relaxation time and in a decrease in signal intensity on gradient-echo images of normal lymph nodes owing to increased susceptibility artifacts. These MR properties are used to aid in detection of microme-
tastases in small lymph nodes. In metastatic nodes, the reticulendothelial system is displaced by tumor deposits and shows deficits in the uptake of USPIO. In patients with head and neck cancer and urologic pelvic tumors, sensitivities for detection have been reported to be good (109,110). At present, the value of MR imaging with USPIO in the detection of nodal metastases in rectal cancer patients is not clear and warrants further evaluation.

CONCLUSIONS AND RECOMMENDATIONS

There is a challenging task for radiologists in helping to improve the therapeutic care of rectal cancer patients. With the recent introduction of treatment strategies such as preoperative radiation and chemotherapy and TME, there is a growing need for an accurate imaging tool to help identify patients who are at risk for local recurrence. On the basis of different risk categories, patients will be treated with different regimens of surgery, radiation therapy, and chemotherapy. The assessment of local spread of the tumor includes determination of the depth of tumor growth in the rectal wall, of the CRM at TME, of the depth of tumor invasion in surrounding pelvic structures, and of the nodal status.

For superficial rectal cancer, which can be treated with surgery alone (TME or transanal resection), endorectal US and endorectal MR imaging are the most accurate staging methods for the assessment of tumor ingrowth in the muscular rectal wall. The choice depends on local availability and expertise. Although both modalities provide clear details of the rectal wall, they are less accurate for the evaluation of the mesorectal fascia and the CRM. For the remaining mobile and fixed rectal cancers, a high-spatial-resolution MR sequence performed with a dedicated phased-array coil is, at present, the most reliable technique for evaluation of the mesorectal fascia and the CRM.

There is evidence that MR imaging is superior to conventional CT for the assessment of tumor invasion in surrounding pelvic structures. The new-generation multi–detector row spiral CT techniques will, however, compete with MR imaging because multi–detector row CT is associated with lower cost, faster acquisition time, and the ability to facilitate staging of distant metastases and local tumor extent in a single examination. The role of multi–detector row spiral CT in rectal cancer has not yet been fully explored, however.

Identification of nodal disease is still a diagnostic problem for the radiologist. Despite the identification of lymph nodes as small as 2–3 mm on high-spatial-resolution images, reliable detection of nodal metastases is presently not possible, because planar imaging relies only on morphologic criteria.

Future research in rectal cancer imaging should therefore be focused on (a) consolidation of the role of high-spatial-resolution MR imaging for determining the CRM and local tumor extent, in larger clinical trials with rectal cancer patients; (b) refinement of the ability to predict the presence of lymph node metastases; and (c) determination of the role of multi–detector row spiral CT in local and distant staging of rectal cancer.

APPENDIX

A standard phased-array MR protocol for rectal cancer consists of T2-weighted turbo spin-echo MR sequences with high spatial resolution (57,64). The strength of T2-weighted turbo spin-echo MR imaging of rectal cancer is that fat tissue remains high in signal intensity. In this way, the tumor contrasts well with the surrounding fat tissue, and even very thin hypointense structures such as the mesorectal fascia can always be identified independent of the body habitus of the patient, owing to the high contrast between the hypointense fascia and the hyperintense fat tissue in and outside the mesorectum.

The specific protocol that we apply in our center is given in the next paragraphs. Gadolinium-enhanced T1-weighted sequences are optional. It is not yet clear whether gadolinium enhancement is really necessary with phased-array MR and would improve local staging of rectal cancer. Although gadolinium enhancement can generate excellent images with very high spatial resolution, preliminary evidence suggests that the addition of gadolinium-enhanced sequences to a standard T2-weighted turbo spin-echo sequence does not improve the diagnostic performance for prediction of the T stage and the CRM (111).

At our institution, phased-array MR imaging is performed at 1.5 T (Gyroscan, Powertrak 6000, NT release 6.2.1; Philips Medical Systems, Best, the Netherlands) with 23.0 mT/m, a rise time of 0.2 msec, and a slew rate of 105 T/m/sec. Subjects are positioned supine and in the feet-first position with the pelvis centered on the proximal end of a quadrature phased-array spine coil (Synergy; Philips Medical Systems).

Sequences used are precontrast T1-weighted two-dimensional turbo spin echo (656/10 msec; echo train length, five; section thickness, 8 mm; intersection gap, 0.8 mm; number of signals acquired, four; matrix, 166 × 256; field of view, 25 cm; acquisition time, 2.18 minutes), gadolinium-enhanced (0.2 ml of gadopentetate dimeglumine per kilogram of body weight, Magnesvist; Schering, Berlin, Germany) T1-weighted two-dimensional turbo spin echo (612/15; echo train length, five; section thickness, 4 mm; intersection gap, 1.2 mm; number of signals acquired, six; matrix, 383 × 512; field of view, 20 cm; voxel size, 0.6 mm³; acquisition time, 7.5 minutes), and T2-weighted two-dimensional turbo spin echo (3,427/150; echo train length, 25; section thickness, 4 mm; intersection gap, 0.8 mm; number of signals acquired, eight; matrix, 175 × 256; field of view, 20 cm; voxel size, 2.43 mm³; acquisition time, 6.5 minutes).

The precontrast T1-weighted sequence is performed in the transverse plane, and the images serve as a reference for accurate planning of the sagittal T2-weighted turbo spin-echo sequence. Sagittal T2-weighted turbo spin-echo images are then used for accurate planning of the transverse and coronal T2-weighted turbo spin-echo sequences. It is especially important to angle these planes exactly perpendicular and parallel to the tumor axis. Gadolinium-enhanced T1-weighted images are obtained with identical angles in the transverse and coronal directions. Patients do not undergo bowel preparation, air insufflation, or intravenous administration of spasmylic medication. The total imaging time (when contrast-enhanced sequences are included) is approximately 45 minutes. Without gadolinium enhancement, the examination can be completed in 30 minutes.

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